PROCEEDINGS

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Determination of the wrong sign decay rate $\mathrm{D}^0 \to \mathrm{K}^+\pi^-$ and the sensitivity to $\mathrm{D}^0 - \bar{\mathrm{D}}^0$ mixing.

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ABSTRACT: The D^0 meson can decay to the wrong sign $K^+ \pi^-$ state either through a doubly Cabibbo suppressed decay or via mixing to the $\overline{D}^0$ state followed by the Cabibbo favoured decay $\overline{D}^0 \to K^+\pi^-$. We measure the rate of wrong sign decays relative to the Cabibbo favoured decay to $(0.383 \pm 0.044 \pm 0.022)\%$ and give our sensitivity to a mixing signal.

1. Introduction

Particle-antiparticle mixing between neutral mesons arises when the mass eigenstates of the production Hamiltonian are not the same as the weak eigenstates which are responsible for the meson decay.

Due to the presence of the weak interaction the physical states are thus a superposition of the mass eigenstates. This superposition splits the mass of the physical states and introduces the possibility of mixing between the mass eigenstates in the form of oscillations. Mixing is defined in terms of two dimensionless parameters: $x = \Delta M/\Gamma$ and $y = \Delta\Gamma/2\Gamma$ where $\Delta M = m_2 - m_1$ and $\Delta\Gamma = \gamma_2 - \gamma_1$ are the differences between the masses and the decay rates of the strong eigenstates respectively, and $\Gamma = (\gamma_2 + \gamma_1)/2$. A recent review of the predictions for the level of mixing can be found in [1].

2. Event Selection

The results presented in this work are based on data collected with the *BABAR* detector [2] at the PEP-II asymmetric e^+e^- storage ring at the Stanford Linear Accelerator Center during the 1999–2000 Run 1. This corresponds to an integrated luminosity of 20.6 fb^{-1}

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recorded *on-resonance* at the $\Upsilon(4S)$ mass and 2.6 fb^{-1} *off-resonance* about 40 MeV/c^2 below this energy.

D^0 candidates produced in $c\bar{c}$ continuum events are selected through the decay chain $D^{*+} \to D^0\pi_s^+$ followed by the decay $D^0 \to K^\pm\pi^\mp$. In this way the production flavour is tagged by the charge of the slow pion from the D^{*+} decay. The decay is then classed as a *right sign decay* if the Kaon has the opposite charge of the slow pion π_s^+ and a *wrong sign decay* if they have the same charge. The charge conjugated D^{*-} decay is treated in the same way.

The event selection criteria are: the momentum of the D^{*+} in the $\Upsilon(4S)$ rest frame above 2.6 GeV/c; particle identification of both D^0 daughters; good track and vertex quality; helicity cut on the Kaon decay angle with respect to the D^0 momentum evaluated in the D^0 rest frame, and $p_t > 0.5$ GeV/c for the pion from the D^0. Finally if multiple overlapping candidates are left in an event the event is rejected. A common vertex fit is made to the D^0, the D^{*+} and the beam spot taking advantage of the small beam spot size $(\sigma_x, \sigma_y, \sigma_z) \approx (120\,\mu\text{m}, 5.6\,\mu\text{m}, 7.9\,\text{mm})$.

3. Analysis method

An unbinned log likelihood fit is performed using the values of $m_{K\pi}$, $\Delta m = m_{(K\pi)\pi_s} - m_{K\pi}$, the proper time t and its estimated error for each D^{*+} candidate. In these variables the *right sign* signal has a very simple shape. It peaks in the mass distributions and follows an exponential convoluted with our resolution model for the time evolution. The *wrong sign* signal has, under the assumption of no *CP* violation, the time evolution modulated by the mixing parameters x' and y':

$$\Gamma(\overline{D}^0(t) \to K^-\pi^+) = \Gamma(D^0(t) \to K^+\pi^-) \approx e^{-t/\tau}\left[R + \sqrt{R}y't/\tau + \frac{1}{4}\left(x'^2 + y'^2\right)t^2/\tau^2\right] \tag{3.1}$$

and convoluted with the same resolution function as the *right sign* decay. R is the time integrated doubly Cabibbo suppressed decay rate. The parameters x' and y' are related to the mixing parameters x and y through a rotation $(x', y') \equiv (x\cos\delta + y\sin\delta, y\cos\delta - x\sin\delta)$ where δ is the unknown phase difference between the Cabibbo favoured and doubly Cabibbo suppressed decay.

In order to have a reliable measurement of the mixing rate we need a good understanding of the background sources in the $(m_{K\pi}, \Delta m)$ plane and of their decay time evolution. The background categories we model are: a real D^0 combined with a fake slow pion; an incomplete D^0 like $D^0 \to K^-\ell^+\nu_\ell$ reconstructed as $D^0 \to K^-\pi^+$; reflections of $D^0 \to K^+K^-/\pi^+\pi^-$; swapped particle ID hypothesis of the K and the π in the D^0 decay, and purely combinatoric background.

We use event mixing as a method to obtain the Δm distribution for the combinatorial and fake slow pion categories directly from data. The idea is to reconstruct D^{*+} candidates from slow pions in one event with D^0 candidates from other events. In this way it is assured that a reconstructed D^{*+} really has a fake slow pion. In Fig. 1 we show a validation of the

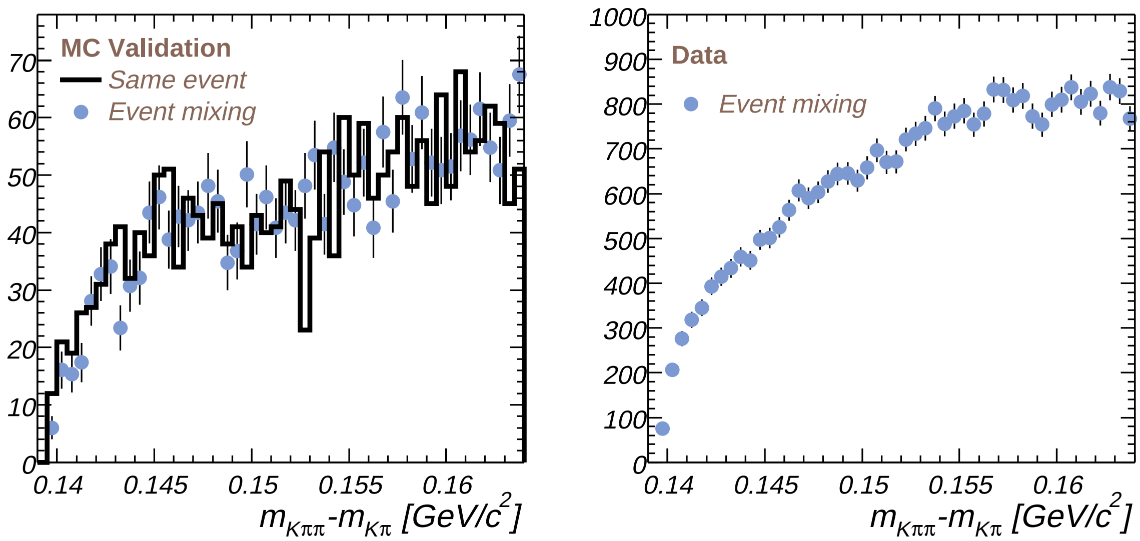

Figure 1: To the left a comparison between the shape obtained from event mixing and the true background shape where the D^0 and slow pion are from the same event. To the right the Δm background shape obtained from event mixing on data.

method on Monte Carlo and the actual Δm distribution we used obtained directly from the data.

4. Results

In table 1 we list the fractional contributions for signal and background sources as obtained from the fit. In Fig. 2 we show the comparison between the fit and the data.

Source	Right sign (%)	Wrong sign (%)
signal	92.16 ± 0.15	6.25 ± 0.57
Real D^0 fake π_s	4.57 ± 0.11	56.5 ± 1.4
Incomplete D^0 and reflections	0.742 ± 0.072	–
Swapped D^0	–	1.29 ± 0.35
Combinatoric	2.525 ± 0.081	36.0 ± 1.1

Table 1: Fractional contribution of signal and background sources obtained from the simultaneous fit to the *right sign* and *wrong sign* sample. $1.804\,\mathrm{GeV}/c^2 < m_{K\pi} < 1.924\,\mathrm{GeV}/c^2$, $\Delta m < m_\pi + 25\,\mathrm{MeV}/c^2$.

In total the selected right sign sample has 58723 candidates and the wrong sign sample 3315 candidates. If we combine this with the signal fractions in table 1 we get 54120 right sign signal events and 210 wrong sign signal events. The ratio between the *wrong sign* signal and the Cabibbo allowed decays is then $R_{WS} = (0.383 \pm 0.044)\%$.

The systematic checks we performed have focused on the log likelihood fit, the selection criteria and detector effects. The mixing parameters are strongly anti-correlated and the

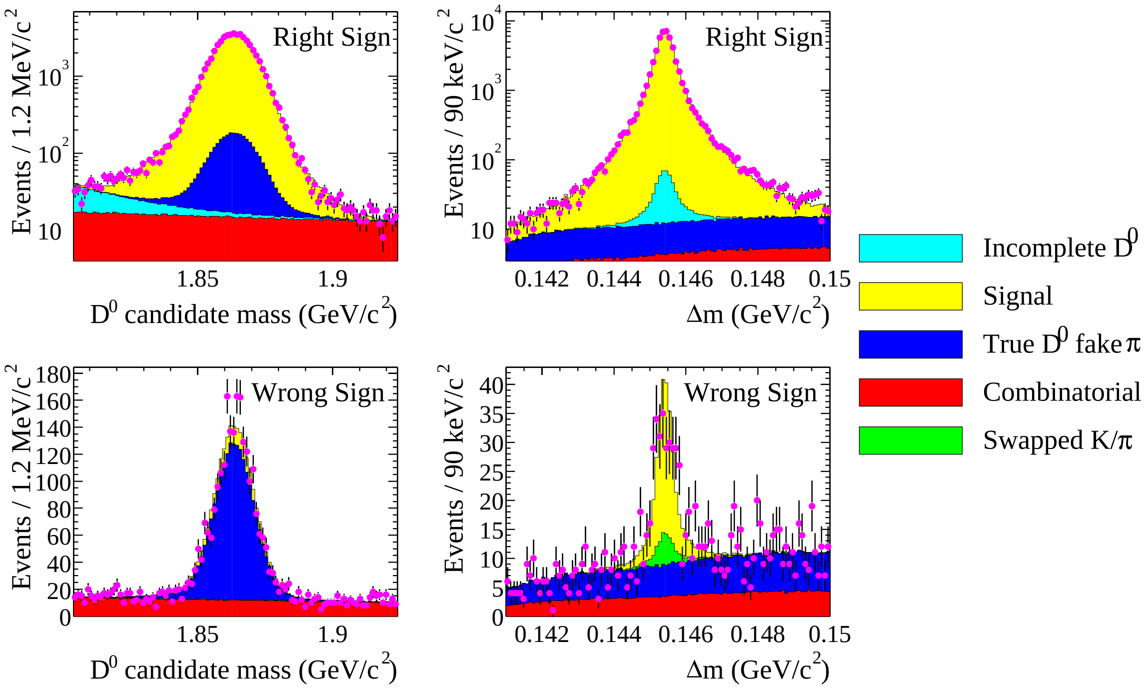

Figure 2: A comparison between the data represented as points with errors and the overall fit to the *right sign* and *wrong sign* D^{*+} candidates. Notice the logarithmic scale for the *right sign* decay.

likelihood space stretches to a non physical region. For this reason, when considering the systematic checks on the mixing parameters, rather than comparing the minimum values obtained from fits to different configurations, we will compare the one and two sigma likelihood contours. A summary of the systematic errors on R_{WS} are given in table 2 and contours for the different systematic checks are overlaid in Fig. 3. The systematic effect from the internal alignment of the silicon tracker is pending the reprocessing of the data and the central value of the mixing fit is kept blinded until then.

By adding in quadrature the systematic errors we obtain the following preliminary result for the wrong sign signal fraction that, in the assumption of no mixing, corresponds to the doubly Cabibbo suppressed decay rate:

$$R_{WS} = (0.383 \pm 0.044(Stat.) \pm 0.022(Sys.))\%. \tag{4.1}$$

This value is compared with other experimental results [3]–[7] in Fig. 4.

References

[1] H. N. Nelson, *Compilation of $D^0 \to \overline{D}^0$ mixing predictions*, `hep-ex/9908021`.

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Type	Variation	Error (%)
Kaon identification	Loose—Tight	0.001
Pion identification	Loose—Tight	0.010
Kaon p_t cutoff	0.1–0.5 GeV/c	0.009
$\cos(\theta^*)$	0.65–1.0	0.006
D^0 mass window	± 40–± 80 GeV/c^2	0.010
Δm window	15–28 MeV/c^2	0.004
SVT track quality		0.011
Background shape		0.003
Background fractions		0.005
$p^*_{D^{*+}}$ cutoff	1.4–2.8 GeV/c	0.004
Prob(χ^2) vertex fit	0.002–0.05	0.001
Other		0.002
Sum in quadrature		0.022

Table 2: Summary of the systematic errors on R_{WS}.

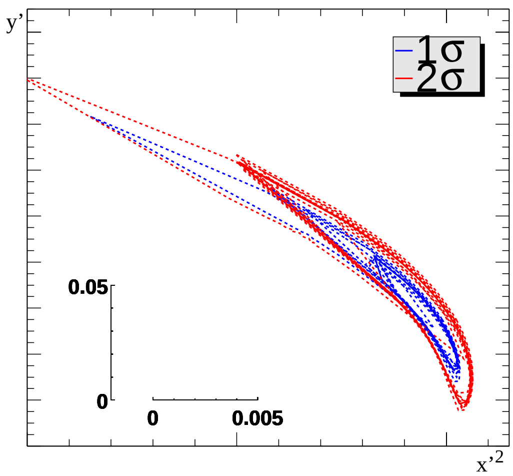

Figure 3: Superposition of all the contours for the systematic checks. The central value of the fit is blind.

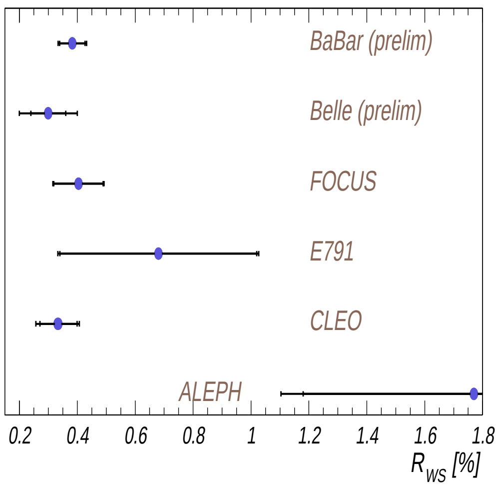

Figure 4: Experimental values for R_{WS}. The results from *BABAR* and Belle are preliminary.

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[7] **FOCUS** Collaboration, J. M. Link *et. al.*, *A study of the decay $D^0 \to K^+\pi^-$*, *Phys. Rev. Lett.* **86** (2001) 2955–2958, [hep-ex/0012048].